Bruising Injury of Tomatoes

Growth Through Agricultural Progress

Marketing Research Report No. 513

UNITED STATES DEPARTMENT OF AGRICULTURE
Agricultural Marketing Service
Market Quality Research Division

Bruising Injury of Tomatoes

Marketing Research Report No. 513

UNITED STATES DEPARTMENT OF AGRICULTURE
Agricultural Marketing Service
Market Quality Research Division

Contents

Washington, D. C. March 1962

Summary

Bruising injury is a major problem in marketing fresh tomatoes The problem is aggravated by the numerous handling operations necessary in marketing; also, the obscurity of symptoms of internal bruising has tended to conceal the importance of the damage.

These studies have demonstrated the hidden and cumulative nature of bruising injury, and also have measured the increase in bruising with each additional handling operation incident to ripening and repacking. A substantial reduction in bruising was obtained, in tests, through careful handling, and through the use of foam-rubber pads.

This study was planned to obtain information that could be used to describe and illustrate the symptoms; to determine the damage found in various laboratory-controlled bruising tests; and to determine the extent of objectionable bruising found during certain phases of commercial handling.

Tomatoes are bruised by fixed pressure, by impacts, and by strong shocks or vibrations. Fruits under fixed pressure for 5 days or longer were permanently pressed out of shape and damaged internally. The affected seed cavities either failed to develop gelatinous tissue or the gel was thick and stringy. Impacts and strong shocks to fruits harvested mature green and bruised during various stages of ripening caused the gel to become cloudy or, in more severe cases, to become watery and disorganized, and the seeds were detached. Water-soaked placental tissue was a typical symptom of bruising in fruits harvested after some color was initiated. Continued bruising in ripening fruits resulted in a general water-soaked condition visible externally.

The amount of bruising injury to mature-green and ripening tomatoes when dropped on a hard surface was observed. The increases in bruising injury caused by repeating the drop, by increasing the height of drop, and by increasing the ripeness of the fruits dropped also were determined. A cushion of 1-inch foam rubber over the hard surface on which the fruits were dropped greatly reduced bruising in tomatoes dropped 6, 12, and 18 inches. The damage from bruising was demonstrated to be cumulative, and the number of locules (seed-containing cavities) affected increased as the severity of treatment was increased.

A limited survey was made to determine the extent of bruising of tomatoes in transit and during ripening and repacking. Tomatoes shipped in standard containers with capacities of approximately 30, 40, 50, and 60 pounds were examined. All were shipped by rail in standard loads that arrived in good order. Bruising varied in tomatoes of the same stage of ripeness at arrival, whether packed in the same kind of container or in different kinds. In general, the ripest fruits had the most external bruise marks and the most objectionable internal bruising. Objectionable bruising was serious in tomatoes in all types of containers studied. Tomatoes that were "pink" at the time of the first sorting were much worse bruised than less ripe fruits. Mature-green fruits that ripened promptly had the least damage. If, however, the green fruits were so immature that they required two or three sortings, bruising was greatly increased.

Bruising Injury of Tomatoes

By Lacy P. McColloch, *Horticultural Crops Branch, Market Quality Research Division, Agricultural Marketing Service*[1]

The Problem of Bruising Injury

Damage from bruising is a major cause of poor quality of fresh tomatoes. This is not a new problem, but one which has long needed additional study. Bruising is intensified because the damage is cumulative, increasing with the numerous handling operations between harvesting and retailing. Moreover, much of the bruising injury is internal, and is not visible on the outside of the tomatoes.

The opinion is sometimes heard in the trade that mature-green tomatoes can withstand rough handling without becoming bruised; but tomatoes are subject to bruising at any stage after harvest. The stage of ripeness does, however, affect the appearance of the bruised area, and, of course, the riper the fruits, the easier they are damaged. Bruising is easily overlooked because much of it is hidden damage. Unless tomatoes are pressed out of shape, soft, or water-soaked, bruising cannot be detected until they are cut.

The structure of the tomato fruit and certain changes that accompany ripening have a direct bearing upon the symptoms of bruising injury. In fully mature-green tomatoes, or in those showing red color, the seeds are embedded in a homogeneous, gelatinous mass of thin-walled cells. These cells are an outgrowth of the placental tissue, are not attached to the seeds or the fruit wall, and normally fill the locular (seed) cavity (*7*).[2] In immature-green fruits, these supporting tissues form a hard, green, mass which surrounds the seeds and fills the seed cavities (fig. 1). As the fruits become fully developed, yet green, and then start to ripen, these cells gradually develop thin walls and become gelatinous and delicate. In normal development (fig. 2), the gelatinous tissue is first amber colored, but takes on a transparent reddish color in fully ripened tomatoes. For convenience, the gelatinous tissue will henceforth be referred to as "gel."

The delicate tissues in the seed cavities or locules are most vulnerable to bruising, and they develop a variety of symptoms. Tomatoes can be bruised by temporary pressure, by continuous pressure for several

---

[1] William Ebersole and Kenneth Wisner, of the same Branch, assisted in conducting the study.

[2] Italic figures in parenthesis refer to items in literature cited, p. 31.

BN-14575

FIGURE 1.—Normal immature-green tomato before the locular tissue has become gelatinous.

days, by one or more impacts, and by strong vibrations or shocks. Bruising from continuous pressure usually occurs when overfilled boxes are stacked and restacked. Most pressure bruising and considerable shock bruising occurs during transit because of the combined action of weight and jolting. Impact bruises develop from dumping, sorting, tossing, or dropping the fruits during handling. There is also considerable shock damage from dropping ripening fruits or setting the filled containers hard in place.

The problem of bruising injury is not confined to those in any one phase of marketing tomatoes, but is the concern of all. The possibility of tomatoes becoming bruised, however, is greater in certain marketing operations than in others. This study is part of a broad program of research designed to reduce marketing costs and expand markets for farm products.

The purpose of this study was to determine the nature and symptoms of bruising injury, to determine the extent of damage under laboratory-controlled treatments, and to report the amount of bruising injury found in a limited survey of commercially handled tomatoes at the time of unloading at a terminal market and during ripening and repacking.

Review of Literature

Using a jolting apparatus to simulate rail transit, Halsey and Showalter (*1*) studied the extent of bruising of three maturities of tomatoes. They found that tomatoes at the "turning" stage developed four times as much bruising injury as mature-green tomatoes, and eight times as much as immature-green fruits.

In shipping tests and in simulated transit tests, Halsey and others (*2*) compared various containers for shipping Florida tomatoes. Pressure bruising was one of the types of mechanical injury evaluated. Fruits crushed, pressed out of shape, or seriously indented were scored as transit bruises. The fruits were not cut, however, so that internal damage was not evaluated.

In 1955, Halsey (*3*) reported a study on bruising of "turning" and "pink" tomatoes during shipping-point handling and packing. This appears to be the first study in which internal bruising was discussed and evaluated. He found that internal bruising was characterized by a water-soaked cellular breakdown of the cross-wall and locular area (seed cavity). The bruising encountered was caused by impacts rather than by fixed pressure, but in tomatoes of the stages of ripening studied, Halsey found the damage the same whether caused by impacts or pressure. Internal damage was not necessarily accompanied by external evidence, and there was a steady increase in the total injury sustained as the tomatoes received more and more handling. Bruising damage was not related to size of fruits.

Other than the water-soaked condition described by Halsey (*3*), no mention has been found of other internal symptoms of bruising injury of tomatoes except brief accounts by the writer (*5*, *6*).

Marks and others (*4*) reported that bruised tomatoes are damaged physiologically. Bruising caused a loss of phosphorylative capacity in the fruits. The loss was reported as partial or complete, depending upon the severity of the bruise and the time elapsed after bruising. They reported complete loss of phosphorylative capacity a few hours after bruising even though the bruised area was restricted to one part of the fruit.

Loss of phosphorylative capacity seems to indicate inability of the fruit to utilize the energy from respiration. Under such conditions, of course, ripening could not take place. In the studies herein reported, bruising did not prevent ripening unless the fruit tissues were extensively damaged so that a general water-soaked condition prevailed.

Study of Symptoms

Procedure

Observations of bruising injury of tomatoes shipped mature-green and those handled during ripening suggested the occurrence of symptoms in addition to the water-soaked tissues described by Halsey (*3*). A series of bruising treatments were, therefore, applied to relate symptoms to various methods of bruising.

Rutgers tomatoes grown at Beltsville, Md., were used in the tests. Bruising treatments were applied to green fruits and to those harvested at various stages of ripening. Color was estimated visually in terms of percentage, judged by a combination of amount of fruit surface colored and the intensity of the color. The methods of bruising corresponded to the manner in which tomatoes are bruised during commercial handling, namely: Fixed pressure, shock, and one or more impacts to the fruits.

Fixed pressure was applied as a temporary force and for a longer period (5 or 6 days). Temporary force was applied by pressing tomatoes against a ½-inch-diameter steel bar resting on the platform of a dial scale. Each tomato was pressed until the desired number of pounds was registered on the scale. Green fruits were pressed to register 10, 15, 20, 30, and 35 pounds. Only 15 pounds of pressure was applied to fruits showing 5 to 40 percent color because greater pressure ruptured the fruits. The pressed area was marked so that it could be observed later. Fixed pressure for 5 or 6 days was applied in two ways: (1) Similar-sized fruits were arranged between two 1-by 3-inch boards which were drawn together with "C" clamps until the sides of the fruits were flattened. (2) Fruits were tightly packed into a lug box until, when lidded, the pack had a high bulge. The packed box was then weighted during ripening.

Impact bruising was done by dropping tomatoes from fixed heights on a hard surface one or more times.

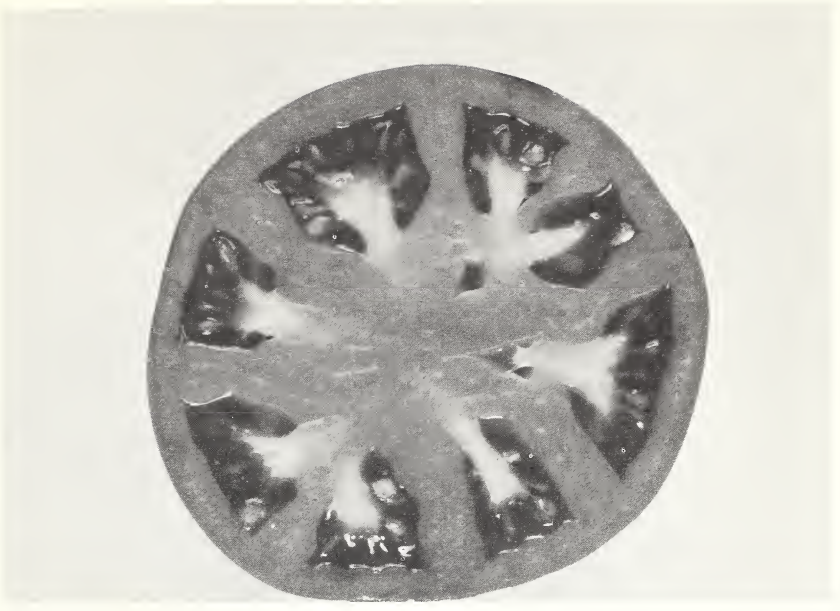
After all bruising treatments, the tomatoes were held at 70° F. until ripe, or a minimum of 5 days, to permit symptoms to develop. External and internal symptoms were noted and described.

Results

Symptoms of bruising injury were influenced by the kind of tissue damaged, by the stage of maturity or ripeness when bruised, by the severity of the treatment, and to a lesser extent by the kind of bruise.

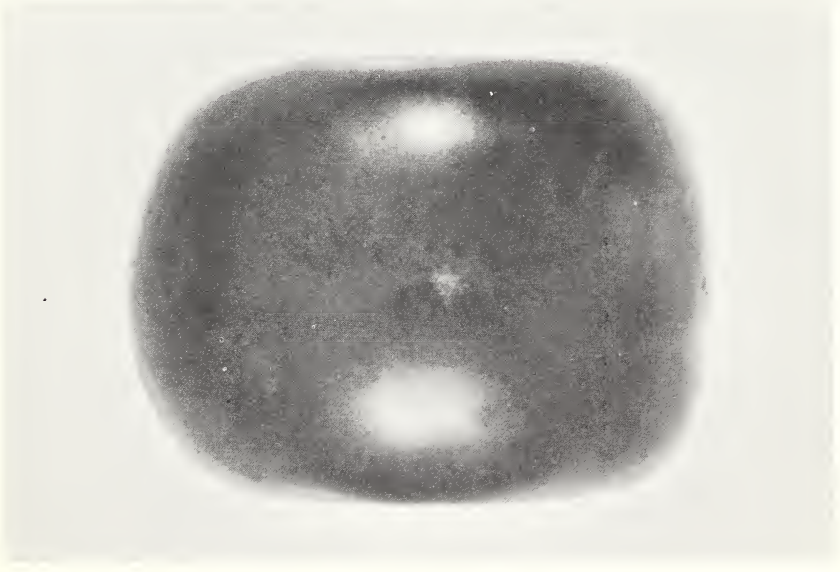
Fruits held under fixed pressure for 5 days or longer were permanently pressed out of shape. Tomatoes with flattened sides (fig. 3) or V-shaped or rounded indentations (fig. 4) were typical of the external symptoms found after prolonged fixed pressure. Serious internal damage invariably accompanied deep external bruise marks. If the pressure was sufficient to permanently damage the locular tissue surrounding the seeds, the tissue failed to change to the typical gelatinous mass of cells that accompany normal ripening. Locular tissue seriously bruised before becoming gelatinous was dry (fig. 5) and usually appeared darkened. In less damaged locules, the development of the gelatinous tissue was incomplete and had a thick, sometimes stringy, consistency (fig. 6) darker than normal.

Mature-green tomatoes pressed on a steel bar were damaged in proportion to the pressure applied (table 1). Pressed fruits immediately showed a groovelike mark from contact with the bar. The mark was much deeper in mature-green fruits pressed to register 30 and 35 pounds than in those pressed to 20 or less. Under the greater pressure, the cells, especially those in contact with the bar, were ruptured and the tissue became water-soaked. The water-soaked condition disappeared during ripening, but serious internal damage remained. When the fruits were cut, the damaged wall showed a



BN–14576

FIGURE 2.—Normal ripening in unbruised tomato. The seeds are embedded in gelatinous tissue.



BN–14577

FIGURE 3.—Tomato held under fixed pressure for 5 days, permanently pressed out of shape.

BN–14579

FIGURE 4.—Indented external bruise mark from fixed pressure in commercial shipment of tomatoes.

BN–14578

FIGURE 5.—Internal condition of mature-green tomato held under fixed pressure 5 days and then ripened. Note damaged tissue causing dry locule.

BN–14580

FIGURE 6.—Tomato damaged from fixed pressure during transit. The damaged gelatinous tissue is thick and stringy.

bleached, hollow area (fig. 7) which resulted from loss of moisture by the crushed tissue. Practically all green fruits pressed 30 and 35 pounds had dry or stringy gel tissue in the affected locules. Those pressed 10 and 20 pounds had less damaged gel tissue which became darker than normal and appeared cloudy.

Tomatoes that were harvested at different stages of ripeness reacted differently to bruising than mature-green fruits (table 1). Fruits showing color when pressed had a tendency to retain part of the water-soaked condition along with the bar mark. These fruits frequently developed a water-soaked condition in the outer wall, cross walls, and placental tissues. The principal symptoms were water-soaked tissues and cloudy gel. In some of the most seriously damaged fruits, the cloudy gel appeared pale and slimy as though bacteria were actively involved. The severity of the damage increased directly in proportion to the ripeness of the fruits, as did all other symptoms noted in fruits bruised during ripening.

Repeated impacts, such as dropping the fruits during ripening, caused damage to the gelatinous tissue surrounding the seeds. Fruits with least damage developed a cloudy condition in the gel, as previously described. Continued dropping of the fruits resulted in extensive damage to the gelatinous tissue. The gel became more liquid, the seeds were detached from the placenta (fig. 8), and the contents spilled out of the seed cavities when the fruits were sliced (fig. 9).

Another symptom of bruising in ripening fruits, especially those harvested after some color was initiated, was a water-soaked condition of the spongy placental tissues at the base of the locules (fig. 10). This was the first location to become water-soaked from bruising.

Irrespective of stage of maturity or ripeness at harvest, if impact bruising of ripe or ripening fruits continued, a general water-soaked condition developed in the walls and seed cavities of the fruit (fig. 11). This condition is also visible externally.

TABLE 1.—*Influence of ripeness and amount of pressure on appearance of bruising injury of tomatoes*

Ripeness [1] and pounds pressure applied		Total fruits	External condition-pressure mark (fruits affected)			Internal condition (fruits affected)							
						Parts watersoaked			Condition of gelatinous tissues				Hollow pockets in outer wall
			Immediately watersoaked	Watersoaked condition remaining	Pressure mark remaining visible	Outer wall	Cross wall	Placenta	Cloudy	Cloudy and slimy	Stringy	Dry	
	Pounds	*Number*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Medium turning	15	20	60	20	15	60	40	90	50	50	0	0	0
Slight turning	15	14	50	21	7	36	0	50	78	21	0	0	0
Very slight turning	15	35	14	0	0	0	0	34	91	9	0	0	0
Mature green	10	20	0	--------	100	0	0	0	75	0	0	0	0
Do	20	20	5	0	65	0	0	0	50	0	10	40	0
Do	30	20	80	0	65	0	0	0	5	0	30	65	60
Do	35	36	100	0	33	0	0	0	0	0	0	100	8

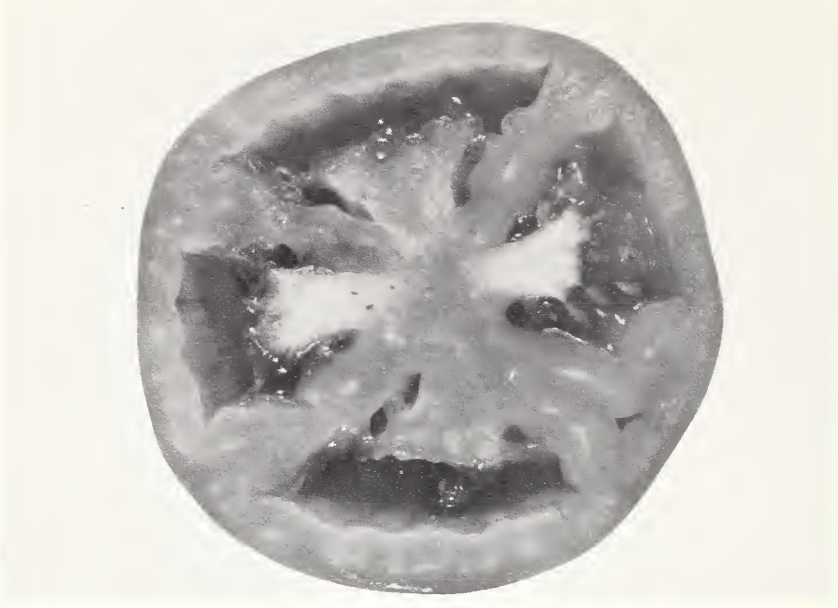
[1] Medium turning, fruits with 25 to 40 percent of surface colored; slight turning, 20 percent colored; very slight turning, 5 to 10 percent colored.

BN–14581

FIGURE 7.—Mature-green tomato pressed to 30 pounds against a steel bar. The bruise mark was first water-soaked, but the damaged wall lost moisture during holding and became hollow and bleached.

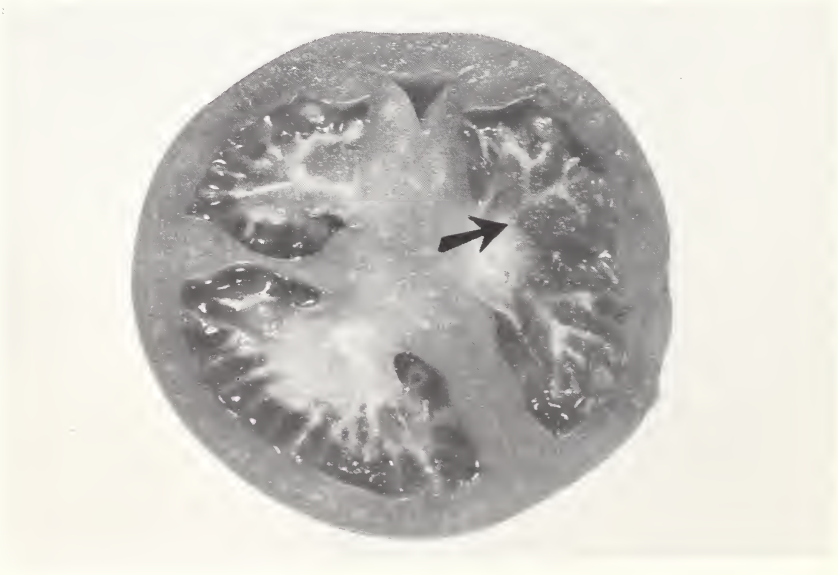
BN–14582

FIGURE 8.—Impacts during ripening caused tomato seeds to become detached from placentae and caused disorganization of the gelatinous tissue surrounding seeds.



BN–14583

FIGURE 9.—Bruising due to impacts and shocks during ripening resulted in a breakdown of the gel, which became watery and spilled out when the tomato was cut.



BN–14584

FIGURE 10.—Water-soaked condition of the spongy placental tissue of tomato, at the base of the locule, caused by bruising.

Finally, after the accumulation of extensive bruising during or after ripening, the fruits became visibly water-soaked and soft. The water-soaked condition extended throughout the fruits, and usually internal tissues were disorganized.

Two abnormal conditions were found in which the gel around the seeds was defective, but the conditions could not be traced to bruising injury.

One of the conditions occasionally found was characterized by a uniform lack of normal gel in all seed cavities. The pale, underdeveloped tissue surrounding the seeds caused them to be slightly obscured and the contents of the locules appeared spongy (fig. 12).

The other abnormal condition was found in most lots of tomatoes from all locations studied. This condition seemed to result from a partial failure of the tissue surrounding the seeds to develop the normal gelatinous consistency and typical reddish amber color. The affected tissue was of a stiff, gelatinous consistency, and the portion between the outer wall and the seeds, or sometimes surrounding the seeds, was discolored. Affected tissue was brown, dark green, or greenish black. This condition was found in many fruits that were carefully clipped from the vines and rested on cotton batting. It was also found in ripe fruits on the vine. In harvested fruits, some of the dark areas appeared traceable to slight external bruise marks. Many, however, showed no connection with bruising. This condition accounts for most of the index ratings of bruising assigned to check fruits which received no special bruising treatment. Dark areas in the gel that were scored as mild bruising were given index ratings of 1 to 4, rarely 5, and usually 1 or 2. Although this condition cannot definitely be ascribed to bruising, the decision was made to continue scoring all fruits with dark areas in the gel as slight bruising. This was done in an effort to keep the data uniform.

BN–14585

FIGURE 11.—General internal water-soaked condition of tomato following repeated impacts to ripening fruit.

BN–14586

FIGURE 12.—Abnormal condition of tomato, not caused by bruising. Cause unknown, but condition present at harvest.

Evaluating Damage Through Controlled Bruising Tests

General Procedure

Rutgers tomatoes grown at Beltsville, Md., and other commercial varieties purchased from commercial sources were used in the controlled bruising tests. Those purchased originated in Florida, Cuba, and Jamaica. Controlled methods of bruising were used on mature-green tomatoes and on those at various stages of ripeness.

Beltsville-grown tomatoes were washed, culls discarded, and the fruits selected for uniformity in test lots. Shipped tomatoes arrived in various stages of ripeness. The ripest fruits and those showing definite bruise marks or other undesirable characteristics were discarded.

Test lots were unified to include fruits of similar size, shape, and maturity or color, depending on whether the test concerned mature-green tomatoes or those showing color.

Some of the bruising treatments were applied to simulate certain handling practices in the tomato industry. Other treatments, however, were used to provide a uniform treatment that could readily be repeated and that would permit a range of bruising injury. Tests were included to show the cumulative effect of repeated bruising, the effect of a single drop, the effect of fruits striking other fruits, and the effect when fruits were dropped from three heights on a hard table compared to those dropped on foam rubber ½ to 1 inch thick.

After the bruising treatments, the fruits were held at 70° F. until fully ripe and then carefully cut with a sharp knife and examined for damage. Tomatoes that were one-half or more colored when bruised were ripened a minimum of 5 days to permit symptoms of bruising injury to develop. Greener fruits were given longer periods to ripen.

The percentages of tomatoes with bruising damage in one, two, or three or more locules were determined. The total number of damaged fruits for all categories also was determined. The severity of bruising was rated, using a score of 1 to 10. A score of 1 indicated very slight damage and scores of 9 and 10 were assigned fruits so damaged as to appear unpalatable. A score of 5 or more was considered objectionable.

Results

Repeated Impacts Resulting in Cumulative Damage

Beltsville-grown tomatoes were subjected to about the same number of handling operations that might be found between harvesting and repacking. Beginning at the mature-green stage, they were dropped from heights that have been observed during the commercial handling of tomatoes. By starting with a nonbruised check lot and then setting aside a test lot after each treatment, it was possible to evaluate the damage caused by each bruising treatment or combination of treatments and to study the cumulative damage of repeated bruising.

The percentages of fruits bruised in one, two, or more locules were relatively low in treatments 2, 3, and 4 (table 2) applied while the tomatoes were green, yet the total of fruits objectionably damaged was large enough to indicate the need for improvement in these operations. The percentage of fruits with one locule damaged did not increase with additional bruising treatments. There was, however, a sharp increase in fruits with three or more locules damaged in lots 5 through 8 as additional bruising was applied. The cumulative damage as a result of repeated bruising is evident in the total percent

TABLE 2.—*Cumulative bruising in Beltsville-grown tomatoes while mature green and after 5 days at 70° F.*

Ripeness and treatment	Total fruits	Tomatoes with objectionable [1] bruising in indicated number of locules			
		One	Two	Three or more	Total
Mature green:	*Number*	*Percent*	*Percent*	*Percent*	*Percent*
1. Check: Not dropped	38	0	0	0	0
2. Dropped in field box at harvest	35	6	0	6	11
3. As No. 2, then dropped on sorting table	37	5	5	8	19
4. As No. 3, then in lug box	37	3	11	8	22
Mature green, then ripened 5 days:					
5. As No. 4, then dropped on sorting table 5 days later	36	3	14	22	39
6. As No. 5, then dropped in lug box	38	3	13	45	61
7. As No. 6, then dropped on sorting table	37	8	16	54	78
8. As No. 7, then dropped in lug box	18	6	33	50	89

[1] Bruising injury rated 5 or more was counted objectionable.

column in table 2. The percentage of fruits damaged was increased by each additional bruising treatment. The greatest increase occurred in lots 5 through 8, in which additional bruising was given following partial ripening after 5 days at 70° F. In general, the severity of bruising as indicated by the average of the index ratings shown for one, two, and three or more locules gradually increased as additional bruising was done.

Effect of Ripeness on Cumulative Bruising From Repeated Impacts

Tomatoes harvested at various stages of ripeness were dropped 6 inches on a hard surface one, two, and four times, to study both cumulative injury and the influence of ripeness on bruising injury.

A single 6-inch drop on a hard surface caused extensive damage in ripening tomatoes (table 3). The riper the fruit when bruised, the greater the damage. Fruits dropped twice were much more damaged than those dropped once. Fruits dropped once, then ripened for 2 days and dropped again, were definitely more damaged than fruits dropped twice in immediate succession.

In general, the most fruits with one locule damaged were found in the mildest bruising treatment. As bruising was increased, more fruits were found with two or more locules damaged. Fruits with 3

TABLE 3.—*Effect of ripeness on cumulative bruising from repeated impacts (6-inch drop on hard surface) to Beltsville-grown tomatoes*

Color class and treatment	Total fruits	Fruits with placental tissue water-soaked	Tomatoes with objectionable [1] bruising in indicated number of locules			
			One	Two	Three or more	Total
	Number	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
60 to 70 percent color:						
Check: Not dropped	60	0	0	0	0	0
Dropped once	42	31	12	45	14	71
Dropped once, 2 days later dropped once again	41	88	2	27	71	100
Dropped twice in succession	54	59	6	33	44	83
Dropped twice in succession, 2 days later dropped twice again	18	100	0	11	89	100
30 to 40 percent color:						
Check: Not dropped	100	0	0	0	0	0
Dropped once	84	51	23	23	16	61
Dropped once, 2 days later dropped once again	52	87	4	10	81	94
Dropped twice in succession	65	54	5	23	55	83
Dropped twice in succession, 2 days later dropped twice again	15	87	0	7	87	93
10 to 20 percent color:						
Check: Not dropped	95	0	0	0	1	1
Dropped once	65	26	15	5	20	40
Dropped once, 2 days later dropped once again	51	61	6	12	63	80
Dropped twice in succession	62	44	8	34	28	69
Dropped twice in succession, 2 days later dropped twice again	31	84	7	3	87	97

[1] Bruising injury rated 5 or more was counted objectionable.

or more locules damaged were most abundant in the most severe treatment. The degree and extent of damage was reflected in the total percentage of fruits with objectionable damage.

The predominate symptom of bruising in these fruits was a water-soaked condition of the placental tissue, typical of that described by Halsey (*3*). The damaged tissue was soft to the touch and disintegrated readily under slight pressure. Fruits less damaged had cloudy gel and some had a slimy condition in the gel.

Influence of Height of Drop and Surface Struck on Bruising

Tomatoes in this series of tests, to measure the influence of height of drop and type of surface struck, were harvested when mature-green. Bruising treatments were applied to some while green, but most treatments were applied during ripening. Bruising was done by dropping tomatoes twice in succession from heights of 6, 12, and 18 inches. One series was dropped on a hard table top and the companion lot was dropped on a 1-inch-thick foam rubber pad. Each series had a check lot that was not dropped.

The purpose was to assess and compare the bruising damage from each height of drop, and to determine the effectiveness of 1-inch foam rubber in reducing bruising.

A special frame (fig. 13) was provided to control the fruits during bruising treatments, in order to protect them from unplanned bruising. The inside of the frame was lined with ½-inch foam rubber. Adjustable shelves permitted different heights of drop. The frame rested on a table tilted by 6-inch blocks under one end. Tomatoes were dropped one at a time from the scheduled height on the hard table. A companion lot was then dropped on 1-inch foam rubber.

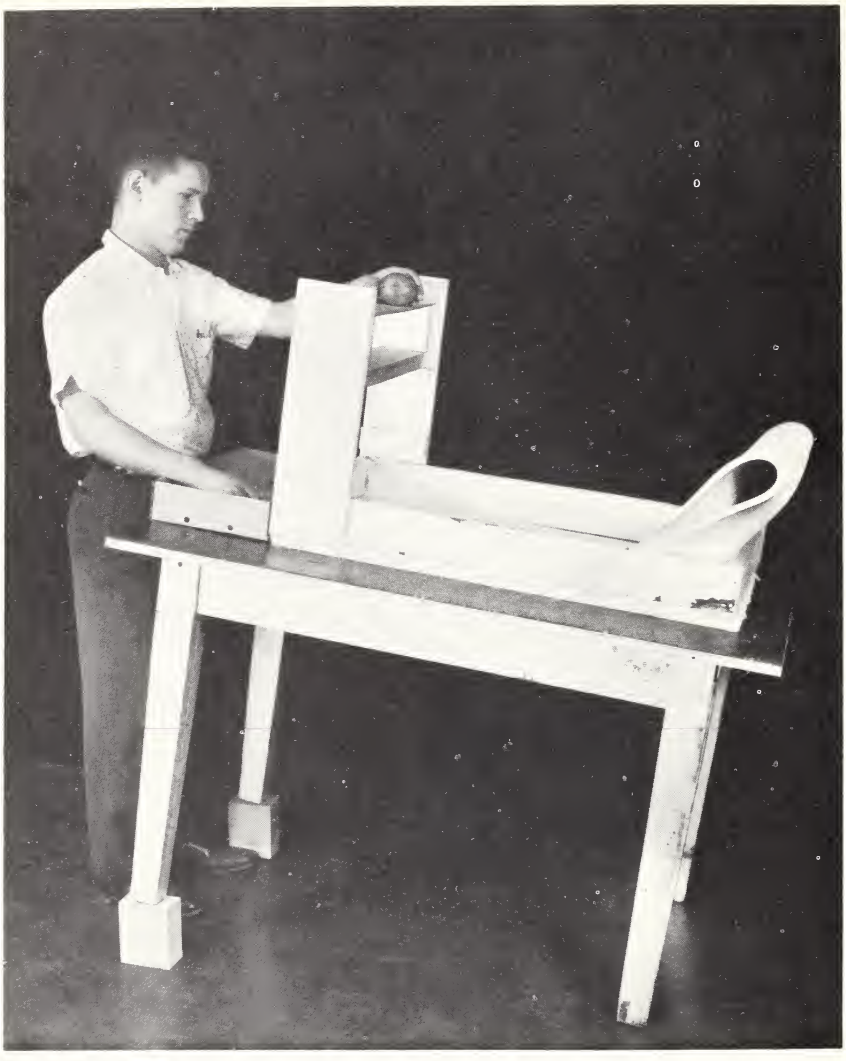
Commercially shipped tomatoes were used in a majority of tests during 1959 and 1960 to observe bruising in a number of varieties. The results of dropping tomatoes twice from a height of 6, 12, and 18 inches on a hard surface and on 1-inch foam rubber are summarized in tables 4 and 5. The summaries on commercially handled tomatoes (table 4) represent 4 tests with mature-green fruits and 16 tests with fruits showing about 30 percent color. The same treatments were also given Beltsville-grown tomatoes. The summarized data (table 5) include one test with mature-green fruits, and four with fruits showing about 30 percent color.

Tomatoes dropped on a hard surface were seriously bruised. The damage increased greatly with each increase in height of drop. Fruits with 20 to 40 percent color were much more damaged than mature-green fruits. One-inch foam rubber did much to reduce damage at all heights tested.

Comparison of Two Thicknesses of Foam Rubber in Reducing Bruising

Beltsville-grown tomatoes of three stages of ripeness were dropped twice in succession from a height of 12 inches on a hard surface and on foam rubber cushions ½ and 1 inch thick.

The fruits were harvested when mature-green from a fall crop in 1960, and ripened to the stages indicated (table 6). The fruits were placed on a tray in a single layer at harvest and carefully handled to minimize bruising prior to treatment. Four tests were made with fruits with 70 to 80 percent color, one test with fruits 40 to 60 percent, and two tests with fruits 20 to 40 percent.



BN–14587

FIGURE 13.—Device used in bruising study to control tomatoes dropped 6, 12, and 18 inches on table top, with and without foam rubber cushion.

Only those fruits showing normal gel free of injury or discoloration were classed as free of internal bruising. From 27 to 36 percent of the check fruits that were not dropped showed defective or slightly discolored areas in the gel. These were scored as slight bruising.

Fruits in all color classes that were dropped 12 inches on a hard surface were damaged, from 77 to 90 percent objectionably so. The damage was characterized in the ripest fruits by disorganized, watery gel that spilled out when the fruits were cut. Slightly more than half the ripest fruits had some water-soaked placental tissue. Fruits in the 20 to 40 percent color class had similar symptoms, but the gel was less damaged and only 23 percent of the fruits showed water-soaked placental tissue.

TABLE 4.—*Influence of height of drop and cushioning on bruising injury to tomatoes purchased wholesale (tomatoes dropped twice in succession from heights of 6, 12, and 18 inches)*

Color class and treatment	Total fruits	Tomatoes with objectionable [1] bruising in indicated number of locules			
		One	Two	Three or more	Total fruits
Mature green:	*Number*	*Percent*	*Percent*	*Percent*	*Percent*
Check: Not dropped	107	3	2	8	13
6-inch drop on hard surface	123	15	21	22	58
6-inch drop on 1-inch foam rubber	124	8	10	7	25
12-inch drop on hard surface	102	16	28	36	79
12-inch drop on 1-inch foam rubber	107	12	7	20	38
18-inch drop on hard surface	121	14	30	47	91
18-inch drop on 1-inch foam rubber	127	11	14	21	46
20 to 40 percent color:					
Check: Not dropped	254	8	4	5	17
6-inch drop on hard surface	212	16	21	34	71
6-inch drop on 1-inch foam rubber	211	6	6	11	24
12-inch drop on hard surface	250	4	26	63	94
12-inch drop on 1-inch foam rubber	251	10	14	22	44
18-inch drop on hard surface	201	9	21	69	98
18-inch drop on 1-inch foam rubber	196	12	19	29	59

[1] Bruising injury rated 5 or more was counted objectionable.

TABLE 5.—*Influence of height of drop and cushioning on bruising injury to Beltsville-grown tomatoes (tomatoes dropped twice in succession from heights of 6, 12, and 18 inches)*

Color class and treatment	Total fruits	Tomatoes with objectionable [1] bruising in indicated number of locules			
		One	Two	Three or more	Total fruits
Mature green:	*Number*	*Percent*	*Percent*	*Percent*	*Percent*
Check: Not dropped	18	0	0	0	0
6-inch drop on hard surface	18	22	11	17	50
6-inch drop on 1-inch foam rubber	18	0	0	0	0
12-inch drop on hard surface	17	18	29	24	71
12-inch drop on 1-inch foam rubber	19	8	8	25	26
18-inch drop on hard surface	18	11	39	44	94
18-inch drop on 1-inch foam rubber	19	5	11	21	37
20 to 40 percent color:					
Check: Not dropped	65	2	5	5	11
6-inch drop on hard surface	64	9	14	42	67
6-inch drop on 1-inch foam rubber	66	9	8	21	38
12-inch drop on hard surface	66	8	20	62	89
12-inch drop on 1-inch foam rubber	65	12	19	37	68
18-inch drop on hard surface	66	3	11	85	99
18-inch drop on 1-inch foam rubber	64	8	16	61	84

[1] Bruising injury rated 5 or more was counted objectionable.

The ½-inch foam rubber cushion greatly reduced bruising, but was much less effective than the 1-inch cushion. Fruits dropped on a 1-inch cushion had practically no damage to two or more locules, while those dropped on ½-inch cushions had an appreciable number (table 6). The percentage of objectionably damaged fruits was also much higher in those dropped on the ½-inch cushion than in the lot dropped on the 1-inch cushion.

TABLE 6.—*Comparison of two thicknesses of foam rubber in reducing bruising of tomatoes in a 12-inch drop*

Color class and treatment	Total fruits	Fruit tissue water-soaked	Tomatoes with objectionable [1] bruising in indicated number of locules			
			One	Two	Three or more	Total fruits
	Number	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
70 to 80 percent color:						
Check: Not dropped	58	0	0	0	0	0
12-inch drop on hard surface	57	53	5	14	70	90
12-inch drop on ½-inch foam rubber	58	12	2	12	21	34
12-inch drop on 1-inch foam rubber	58	3	2	3	5	10
40 to 60 percent color:						
Check: Not dropped	18	0	0	0	0	0
12-inch drop on hard surface	18	44	6	22	56	83
12-inch drop on ½-inch foam rubber	18	17	17	11	0	28
12-inch drop on 1-inch foam rubber	18	6	0	0	0	0
20 to 40 percent color:						
Check: Not dropped	30	0	0	0	0	0
12-inch drop on hard surface	30	23	3	33	40	77
12-inch drop on ½-inch foam rubber	30	0	0	13	3	17
12-inch drop on 1-inch foam rubber	30	0	3	0	0	3

[1] Bruising injury rated 5 or more was counted objectionable.

Bruising Caused by Tomatoes Striking One Another

The separation of stages of ripeness during the sorting of tomatoes is a standard practice of the commercial repacker. The fruits are usually divided into four or five color classes. Fruits showing color are either tossed into appropriate lanes on a conveyor belt from which they drop off into lug boxes, or are tossed into nearby lugs. The first fruits to fall strike the bottom of the box. Thereafter, falling fruits strike one another. Green fruits travel to the end of the belt and drop into lug boxes.

The purpose of this test was to determine the bruising that may result from one fruit striking another during sorting.

Beltsville-grown tomatoes were carefully harvested in single-layer trays, when just showing color, and when mature-green. Those showing color were ripened at 70° F., until one lot showed 80 to 86 percent color, one lot 65 to 80 percent, and one 30 to 40 percent.

To control the fruits during treatment, a bin was devised, similar to one used in sorting ripe fruits in a nonmechanized commercial re-

packing plant. The surface of the small-scale model was lined with 1-inch-thick foam rubber. This bin was used for the three lots of test fruits in various stages of ripeness.

The bottom of the bin was covered with marked tomatoes, and test fruits of the same stage of ripeness were tossed about 2 feet onto the marked fruits and on one another until all had been tossed in the bin. The marked fruits of the bottom layer were discarded and the tossed fruits were placed in a single layer in trays and ripened at 70° F., then cut and the bruising data obtained.

Mature-green fruits were handled somewhat differently. The bruising treatment simulated the dropping of fruits from the conveyor belt to lug boxes. The boxes were supported at the ends only, which allowed the bottom of the box to absorb some of the force of the dropping fruits. The bottom of the box was covered with marked fruits and the test fruits were dropped about 8 inches on the marked fruits and on each other. The marked fruits were discarded and the test fruits ripened and the bruising noted.

The bruising injury that tomatoes receive from being tossed one time on other fruits and, in some instances, from having other fruits strike them is given in table 7.

Most of the check fruits (not tossed) were free of bruising. Those scored did not have typical bruising injury, but had dark areas in the margin of the gel, described under general procedure as defective gel. The ratings assigned were low, usually 1 or 2 and rarely 3, so there was no objectionable bruising (ratings of 5 or more).

Fruits that were tossed showed darkened areas similar to those on check fruits, but tossing the fruits aggravated the condition. Excepting the ripest tomatoes, bruising was not serious. Tomatoes showing color were softened some, however, by being tossed on other fruits. Symptoms of bruising found were cloudy gel and water-soaked placental tissue (fig. 10).

Although serious bruising was not extensive, the practice of tossing ripening tomatoes on an unpadded surface is undesirable because of the cumulative nature of bruising injury.

TABLE 7.—*Bruising caused by one tomato striking another when tossed into a container in sorting*

Color class and treatment	Total fruits	Internal bruising in fruits after ripening		
		None	Slight	Objectionable [1]
	Number	*Percent*	*Percent*	*Percent*
80 to 86 percent color:				
Check, not tossed	18	72	28	0
Tossed on other fruits	18	33	28	39
65 to 80 percent color:				
Check, not tossed	57	82	18	0
Tossed on other fruits	120	28	54	18
30 to 40 percent color:				
Check, not tossed	58	40	60	0
Tossed on other fruits	58	12	72	16
Mature green:				
Check, not dropped	145	75	25	0
Dropped 9 inches on fruits	126	34	64	2

[1] Bruising injury rated 5 or more was counted objectionable.

Mature green tomatoes dropped 9 inches once on other fruits in a lug box showed little objectionable damage. Defective gel was darker and there were more instances of cloudy gel in dropped than in non-dropped fruits.

A Comparison of Bruising Injury Resulting From Careful and Rough Handling at Unloading

One of the handling operations where bruising appears to be increased is during unloading and restacking. California tomatoes of 5x6 size were used for the test. They were bulk-packed in lug boxes either with liners and fiberboard lids or with slatted lids and a chipboard liner under the lid.

In each of two cars, a single lug was taken from the middle layer and given rough handling. Two lugs from the top, middle, and bottom layers from each of these two cars were carefully handled. In a third car, one lug from the top, middle, and bottom layers was roughly handled, and an adjacent lug from the same layers was carefully handled as a check.

The check lugs were carefully carried, one at a time, from the car on arrival, and set aside to avoid any additional bruising.

Each lug that received rough handling was set with force on the conveyor, and again on the pallet, and finally dragged from a hand truck and allowed to drop to the floor, a height of 12 inches. Thereafter, care was taken to prevent further bruising. The lugs were hauled in a single layer to the laboratory, where the fruits were carefully sorted into single-layer trays to ripen. The fruits were segregated according to stage of ripeness as "firm ripe" (showing 75 percent or more of the surface colored), "pink" (50 to 75 percent of surface colored), "breakers" (5 to 50 percent of the surface colored), and "green" (no yellow or red color). The rough treatment given did not necessarily represent commercial handling, but was planned to demonstrate the damage from rough handling.

Fruits showing external bruise marks an inch or more in diameter were marked. Data on internal bruising were taken separately on fruits with and without serious external bruise marks. "Firm ripe" and "pink" tomatoes were held for 5 to 7 days to permit symptoms of bruising damage to develop. Fruits classed as "breakers" and "green" were held until ripe enough to eat before data on bruising were obtained.

Because of differences in maturity and perhaps temperature, tomatoes in commercial packs ripen at different rates during transit and after reaching their destination. An accurate comparison of treatments, therefore, cannot be made on the total fruits in containers. A more satisfactory method appears to be a direct comparison of fruits of the same stage of ripeness ("ripe," "pink," "breakers," and "green") at arrival, in the two treatments. Fruits that arrived as "pink" and "firm ripe" were highly subject to transit bruising. Data on "pink" and "firm ripe" were combined because of their similar susceptibility to bruising and small numbers.

Bruising, both external and internal, was worse in fruits that arrived at destination as "firm ripe" and "pink" than in less ripe fruits. Tomatoes that arrived as "breakers" had an intermediate amount of damage, and those that were green had the least bruising (table 8). External bruise marks were not materially increased by the rough handling at unloading, but internal bruising was greatly increased.

TABLE 8.—*Effect of careful and rough handling at unloading on bruising injury of tomatoes shipped from California*

Color class and treatment	Total fruits	Fruits with external bruise marks	Tomatoes with objectionable [1] internal bruising		
			With external bruise marks	Without external bruise marks	Total
	Number	*Percent* [2]	*Percent* [2]	*Percent* [2]	*Percent* [2]
Ripe and pink:					
Carefully handled	342	58	49	25	74
Roughly handled	200	52	51	44	95
Breakers:					
Carefully handled	389	41	23	12	35
Roughly handled	105	44	37	36	73
Mature green:					
Carefully handled	559	14	4	2	6
Roughly handled	80	23	18	16	34

[1] Bruising injury rated 5 or more was counted objectionable.
[2] Based on total number of fruits (column 2).

Internal bruising was much more serious in fruits that showed external evidence such as flattened or indented areas.

Bruising damage was greatly intensified in "firm ripe" and "pink" tomatoes that were handled roughly during unloading. The gel tissue in many fruits was disorganized and watery, and spilled out when the fruits were cut. The shock or jarring caused by setting the lugs down hard was very damaging to fruits in the "breaker" stage also. In general, the symptoms ranged from a greenish to cloudy gel, and many fruits, especially those with external bruise marks, had disorganized and watery gel. Even the green fruits showed some serious gel breakdown.

Bruising Injury Related To Commercial Handling

A limited survey was made to determine the extent of bruising of tomatoes at the end of the transit period and during commercial ripening and repacking.

Bruising of Tomatoes Shipped in Containers Carefully Removed From Rail Cars

Procedure

Tomatoes shipped in containers having approximately the following net capacities were examined: Lug boxes, 30 pounds; fiberboard boxes, 40 and 50 pounds; and wirebound boxes, 60 pounds.

The tomatoes, shipped in mechanically refrigerated cars, originated in California or Florida. The loads were all of normal height and arrived in good order with practically no shifting. Except for the samples in 50-pound fiberboard and 60-pound wirebound boxes from Florida, all samples were carefully carried from the rail cars. In the exceptions, the test packages were taken from the top of three separate skidloads after the cars were unloaded.

To avoid additional bruising, all containers of tomatoes were carefully handled and hauled in a single layer to the laboratory. The fruits were immediately unpacked, external bruise marks identified, stages of ripeness segregated, and the fruits placed in trays in a single layer to ripen. When the tomatoes were fully ripe, they were cut and the extent of internal bruising was determined.

This study was not intended to evaluate shipping containers in relation to bruising, but to show the amount of bruising found at the end of the transit period in the containers used.

Results

Bruising varied greatly in tomatoes of the same stage of ripeness at arrival, whether packed in the same kind of container or in different kinds (tables 9, 10, and 11). The presence of external bruise marks indicated that the tomatoes had been held under fixed pressure for several days. The percentages of fruits pressed out of shape reflected the extent to which individual fruits were subjected to pressure from other fruits within the container, or the weight of other fruits and containers on them, especially during transit. In general, the fruits that were ripest at arrival had the most external bruise marks and the highest percent of internal bruising damage. Fruits with serious external bruise marks invariably had the greatest amount of objectionable internal bruising.

TABLE 9.—*Bruising found in tomatoes that were "firm ripe" or "pink" at end of transit period (containers carefully removed from rail cars)*

Container type	Source	Packages examined	Total fruits	Fruits with external bruise marks	Tomatoes with objectionable [1] internal bruising		
					With external bruise marks	Without external bruise marks	Total
		Number	*Number*	*Percent* [2]	*Percent* [2]	*Percent* [2]	*Percent* [2]
Lug box (30 pounds).	Cal.	6	116	67	59	24	83
Lug box (30 pounds).	Cal.	6	122	47	34	23	57
Lug box (30 pounds).	Cal.	3	104	60	55	28	83
Lug box (30 pounds).	Cal.	------	312	29	17	17	34
Fiberboard (40 pounds).	Fla.	2	25	72	44	16	60
Fiberboard (50 pounds).	Fla.	3	135	47	41	32	73
Wirebound (60 pounds).	Fla.	3	44	96	59	2	61
Wirebound (60 pounds).	Cal.	3	69	73	61	17	78
Wirebound (60 pounds).	Cal.	3	166	59	33	7	40

[1] Bruising injury rated 5 or more was counted objectionable.
[2] Based on total number of fruits (column 4).

TABLE 10.—*Bruising found in tomatoes that were "breakers" at end of transit period (containers carefully removed from rail cars)*

Container type	Source	Packages examined	Total fruits	Fruits with external bruise marks	Tomatoes with objectionable [1] internal bruising		
					With external bruise marks	Without external bruise marks	Total
		Number	*Number*	*Percent* [2]	*Percent* [2]	*Percent* [2]	*Percent* [2]
Lug box (30 pounds).	Cal.	6	149	53	34	16	50
Lug box (30 pounds).	Cal.	6	108	37	14	5	19
Lug box (30 pounds).	Cal.	3	132	31	19	12	31
Lug box (30 pounds).	Cal.	------	206	13	6	6	12
Fiberboard (40 pounds).	Fla.	2	22	64	32	4	36
Fiberboard (50 pounds).	Fla.	3	120	45	34	23	57
Wirebound (60 pounds).	Fla.	3	65	59	23	14	37
Wirebound (60 pounds).	Cal.	3	227	47	37	23	60
Wirebound (60 pounds).	Cal.	3	157	20	6	3	9

[1] Bruising injury rated 5 or more was counted objectionable.
[2] Based on total number of fruits (column 4).

TABLE 11.—*Bruising found in tomatoes that were green at end of transit period (containers carefully removed from rail cars)*

Container type	Source	Packages examined	Total fruits	Fruits with external bruise marks	Tomatoes with objectionable [1] internal bruising		
					With external bruise marks	Without external bruise marks	Total
		Number	*Number*	*Percent* [2]	*Percent* [2]	*Percent* [2]	*Percent* [2]
Lug box (30 pounds).	Cal.	6	254	19	7	1	8
Lug box (30 pounds).	Cal.	6	267	9	1	2	3
Lug box (30 pounds).	Cal.	3	37	3	3	0	3
Lug box (30 pounds).	Cal.	------	72	14	1	3	4
Fiberboard (40 pounds).	Fla.	2	147	30	1	2	3
Fiberboard (50 pounds).	Cal.	3	108	19	8	7	15
Wirebound (60 pounds).	Fla.	3	335	32	7	3	10
Wirebound (60 pounds).	Cal.	3	260	10	4	10	14
Wirebound (60 pounds).	Cal.	3	98	6	1	0	1

[1] Bruising injury rated 5 or more was counted objectionable.
[2] Based on total number of fruits (column 4).

Objectionable bruising was present in 34 to 83 percent of tomatoes that were "pink" or "firm ripe" at arrival, in 9 to 60 percent of tomatoes that were "breakers" at arrival, and only in 1 to 15 percent of tomatoes that were green at arrival.

While bruising found at arrival was the accumulation since harvest, the principal damage appeared to have occurred after the tomatoes were packed, and especially during transit. These tests show that objectionable bruising was serious in tomatoes in all shipping containers studied.

Bruising Related to Handling Practices During Commercial Ripening and Repacking Tomatoes

This study was conducted to determine the increase in bruising that occurs during the handling incident to ripening, and to learn whether there are certain handling practices that cause an unusual amount of bruising.

Receivers who handle and ripen tomatoes in volume use similar handling practices. For example, tomatoes are usually unloaded one package at a time and restacked on a pallet. The palletload is moved in and out of the ripening room as a unit. Tomatoes are usually held in original containers in the ripening room for 1 to 4 days before they are sorted for color. Fruits in original packages are then dumped on

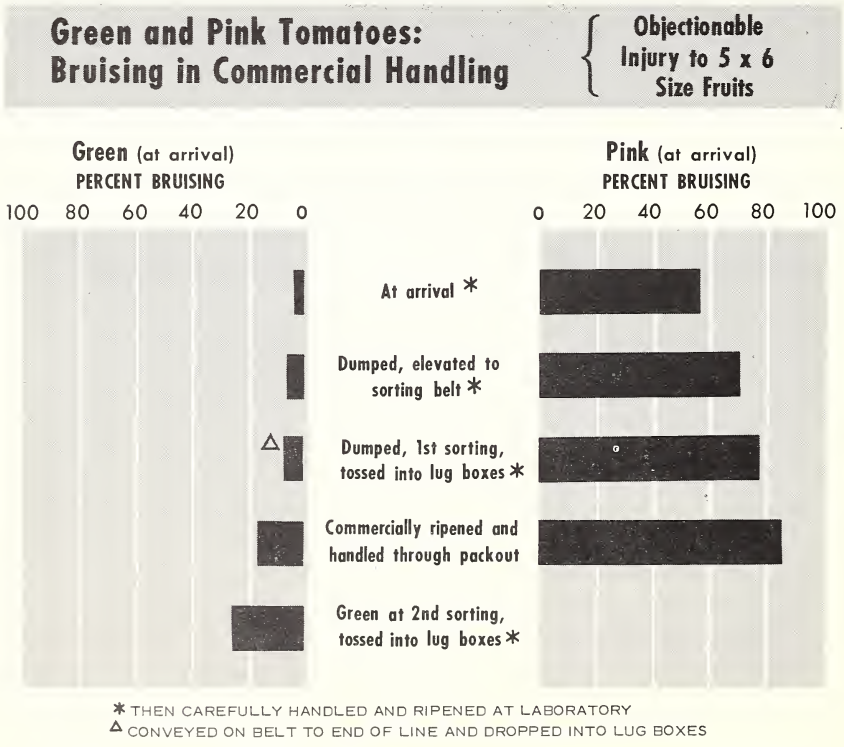


FIGURE 14.

a conveyor for sorting. Workers segregate fruits into several classes according to stage of ripeness. Typical classes are "ripe," "pink," "breaker," and "green." These classes may be defined as: "Ripe," 75 percent or more color; "pink," 50 to 75 percent color; "breakers," trace to 50 percent color; and "green," no yellow or red color. Fruits in each class are either tossed into nearby lugs or permitted to exit through a side gate on the conveyor and drop into lug boxes. Ripened fruits are packed from bins or lugs. Fruits that require further ripening are returned to the ripening room. Tomatoes that were green or, in some operations, "breakers" at the previous sorting are again dumped and the stages of ripeness segregated as described above. This process of packing the ripe fruit and re-sorting mixed stages is continued until all fruits have ripened.

Procedure

Florida-grown tomatoes of U.S. No. 1 grade were used in the tests. Samples were taken from one car which arrived in April and another in May. Both cars arrived in good order and were unloaded promptly.

Two sizes of tomatoes shipped in 40-pound fiberboard boxes in one car, and one test with 5 x 6 size shipped in 60-pound wirebound boxes in the other car, were followed through the ripening and han-

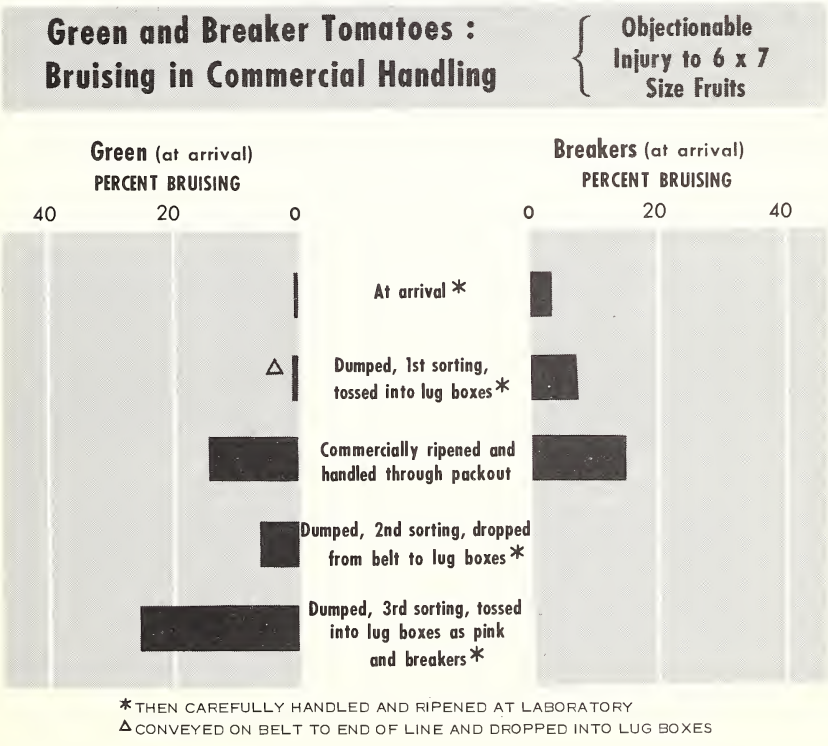


FIGURE 15.

dling of a typical repacking plant. The original plan was to follow a palletload of tomatoes through the handling involved in unloading, sorting, ripening, and repacking, and to determine bruising that occurred during that time. This was not practical, however, and studies on the 5 x 6 size in the first car were completed only on that part of a palletload that was pink or green at the first sorting. Of the 6 x 7 size, bruising studies were made on that part of a palletload of tomatoes that were "breakers" and those that were green at the first sorting. From the second car, fruits of 5 x 6 size from one palletload that were "pink," "breakers," and "green" at the time of first sorting were followed through ripening to study bruising.

A sample of tomatoes taken at the time of unloading served as a check to indicate the amount of bruising in the fruits at the time of arrival. Check samples were carefully moved to the laboratory, unpacked, and sorted for ripeness, and each stage was placed in a single layer to ripen.

Other samples, as indicated in figures 14, 15, and 16, were taken at points in the handling and ripening operations to study bruising. The purpose of each sample taken was to measure bruising up to that point, and to determine to what extent increased handling had increased bruising. Special care was then taken to avoid additional bruising.

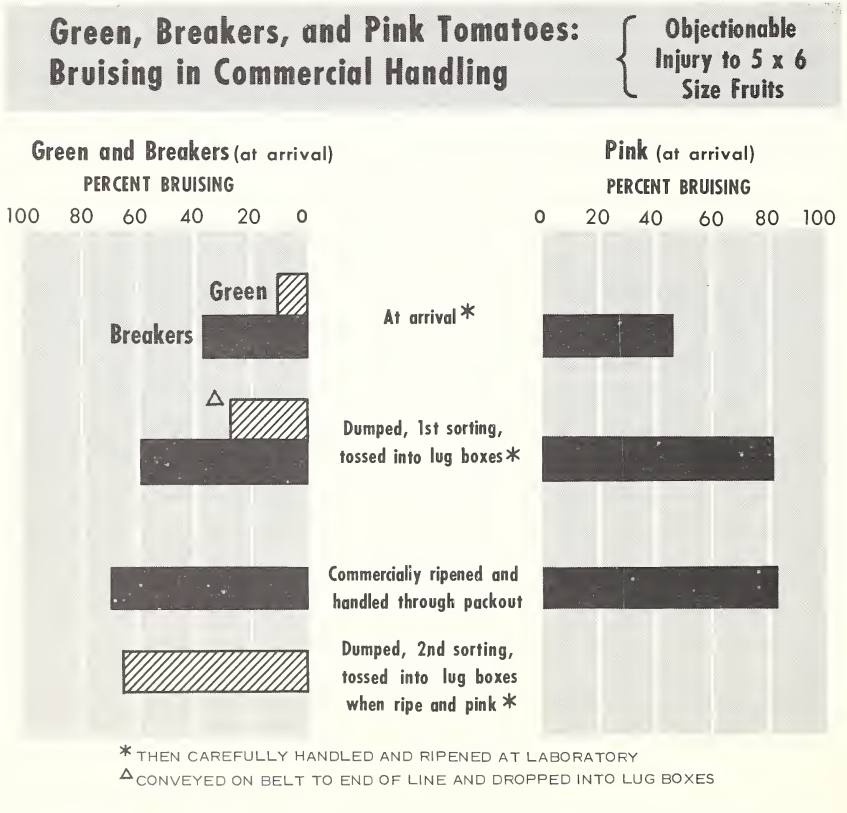


FIGURE 16.

Each sample was carefully hauled to the laboratory and the fruits were placed in a single layer in containers for ripening.

Fruits considered "firm ripe" when sampled were held 5 days to permit symptoms of bruising to develop. They were then cut, and data on bruising obtained. Other fruits were held longer than 5 days until fully ripe before data on bruising were obtained.

Results

Each additional handling produced a marked increase in bruising (figs. 14, 15, and 16). There was a striking difference in amount of bruising in tomatoes at arrival and after the period of handling and ripening.

Tomatoes that were "pink" at the first sorting, after 2 days of ripening in the shipping container, were much more severely damaged by bruising than less ripe fruits (figs. 14 and 16). "Breakers" had an intermediate amount of bruising, and tomatoes that were "green" at the first sorting had the least. Fruits that were so green at arrival that two or three sortings were necessary during ripening, however, developed from two to nearly four times as much objectionable bruising as fruits that were green at the first sorting but ripened promptly.

The sampling method used did not reveal any one point in the handling as the location of the principal cause of bruising. However, handling practices contributed to a steady and serious cumulation of bruising damage.

Literature Cited

(1) Halsey, L. H., and Showalter, R. K.
1953. how does tomato maturity affect market quality. Proc. Assoc. of Southern Agr. Workers. pp. 134–135.

(2) Halsey, L. H., McColloch, L. P., Spurlock, A. H., and Showalter, R. K.
1955. containers for shipping florida tomatoes. Fla. Agr. Expt. Sta. Bul. 560.

(3) Halsey, L. H.
1955. preliminary studies of bruising of "turning" and "pink" tomatoes caused by handling practices. Proc. Fla. State Hort. Soc 68: 240–243.

(4) Marks, Joy D., Bernlohr, Robert, and Varner, J. E.
1957. esterification of phosphate in ripening fruit. Plant Physiol 32: 259–262.

(5) McColloch, Lacy P.
1957. handling tomatoes the quality way. American Vegetable Grower 5: 40–42.

(6) McColloch, Lacy P.
1960. bruising injury of tomatoes. Fourteenth National Conference on Handling Perishable Agricultural Commodities. pp. 75–79. Purdue University, Lafayette, Ind. March 1–3.

(7) Smith, Ora.
1935. pollination and life history studies of the tomato (lycopersicon esculentum mill). Cornell Univ. Agr. Expt. Sta. Memoir 184, 16 pp.

U.S. GOVERNMENT PRINTING OFFICE : 1962 O—622013